Algorithms for Sink Mobility in Wireless Sensor Networks to Improve Network Lifetime

Metin Koç and Ibrahim Körpeoglu

Abstract Sink mobility is an effective solution in the literature for wireless sensor network lifetime improvement. In this paper, we propose a set of algorithms for sink site determination (SSD) and movement strategy problems of sink mobility. We also present experiment results that compare the performance of our algorithms with other approaches in the literature.

1 Introduction

Several schemes are proposed in the literature to minimize the total energy consumption in the WSN and thus improve the wireless sensor network lifetime: power adjusting when transmitting messages, developing energy-efficient MAC or routing protocols, etc. Making the data collection node (or sink) mobile appears to be another approach for improving the lifetime of WSNs. In such a network, the packet traffic flows from the base station to the leaf nodes, that is, all packets of the network are delivered to the sink node via its first-hop neighbors. This situation causes these nodes to deplete their energy faster than the other nodes in the network. Therefore, sink changes its position periodically by fairly delegating the sink's neighbor role among the sensor nodes to balance the remaining energy levels of the nodes to improve the wireless sensor network lifetime.

In this paper, we propose two sink site determination (SSD) algorithms and give a movement strategy for the sink used after the sojourn time expires. Simulation results show that proposed algorithms perform better than its counterparts and improve the wireless sensor network lifetime effectively.

M. Koç (✉) · I. Körpeoglu
Department of Computer Engineering, Bilkent University, 06800 Ankara, Turkey
e-mail: mkoc@cs.bilkent.edu.tr

E. Gelenbe et al. (eds.), *Computer and Information Sciences II*,
DOI: 10.1007/978-1-4471-2155-8_21,

The rest of the paper is organized as follows: Sect. 2 describes the proposed algorithms. Results of the experiments are presented in Sect. 3. Finally, Sect. 4 concludes the paper.

2 Proposed Algorithms

The main motivation behind sink site determination (SSD) algorithms is to decrease candidate migration points in the deployment area to minimize the time needed to determine which sink site to next visit after the sojourn time at the current sink site expires.

2.1 Neighborhood-Based SSD Algorithm

Sometimes it can be difficult to know the exact boundaries of the deployment area and the coordinates of each sensor node in the region. In such cases, neighborhood information of the nodes can be used for determining candidate sink positions.

We present a greedy heuristic algorithm for dealing with dominating set problem (choose q nodes from out of n nodes such that the union of the neighbors of these nodes covers all the nodes in the area.). In the beginning, after determining the neighborhood information of each node, the sink node sorts these nodes in descending order according to their number of neighbors. Then the heuristic algorithm takes the coordinate of the node (a *contributed* node) with the most number of neighbors in the beginning and put those neighbors to the current neighbor list. After first contributed node is chosen (the node with the most number of neighbors), its neighbors are saved in *coveredNodes* list. The *uncoveredNodes* list is simply calculated via taking set difference of universal set (i.e., all nodes) and *coveredNode* list. After initialization of those lists, node that has the maximum number of common elements (neighbors) with *uncoveredNodes* is chosen as the next contributed node. Then its neighbors are added to *coveredNodes* list and *uncoveredNodes* list is updated. This iteration continues until *uncoveredNodes* list becomes empty (*coveredNodes* equal to universal list).

2.2 Coordinate-Based Sink Site Determination Algorithm

It is possible to group nodes using their coordinate values (if they are known) on the sink side. In the coordinate-based sink-site determination algorithm, we divide the deployment area into squares such that each one's length is equal to the transmission range. That enables us to group (cluster) nodes that can be a sink's neighbors in any round and compare their energy levels and decide which sub-area to move to in the next round. The number of areas dynamically changes according to the transmission range values.

The distance between any two neighbor sink sites is R, where R is the maximum transmission range. Each sink site is ideally placed at the center of the allocated area. After determining the centers of each sub-square, sparse areas are eliminated if their *density* is below the threshold, where the threshold is determined by dividing the number of nodes by the number of sub-squares.

A dynamic sink site selection algorithm (either neighborhood- or coordinate-based) provides us to eliminate the areas that are on inaccessible terrains which prevents the sink to move and stay at that point.

2.3 Movement Strategy

After candidate sink sites are determined, the sink node moves to the densest point of the area (first migration point). If the sojourn time expires (either exceeds t_{min}—the minimum time that a sink should stay on the current site—or a change in energy level occurs), the sink examines the minimum remaining energy value in each candidate migration point, which means the minimum energy value among the nodes' energy values that fall into the squares, using the information in the last received packets. Then it moves to the point where the minimum remaining energy level is maximum among the sites that have not been visited yet [visited max–min (VMM)]. When we say 'have not been visited', we mean that a site cannot be visited until the sink has moved to all of the candidate migration points once. After all visits have been completed, then the *visited* flag will be set to zero for all of the sink sites and they all become available to visit again.

3 Simulation Results

3.1 System Model and Main Parameters of the Simulation

Sensor networks in the simulation have N static sensor nodes and a mobile base station. Those nodes are deployed to a region of interest randomly. Square areas are used in the simulations, which are generally either $300 \times 300\,\mathrm{m}^2$ or $400 \times 400\,\mathrm{m}^2$. The energy model and the radio characteristics used in the simulations comes from [2]. In this work, we define the network lifetime as the period of time until the first node dies, which is a commonly used definition in the literature.

Three existing SSD approaches in the literature are summarized in Fig. 1. P1 and P2 are given as sink sites in [3]. In Fig. 1a, center points of four grids are chosen as possible sink sites, whereas the second one takes four corner points and the center of the big square (coordinates are given for a $100 \times 100\,\mathrm{m}$ square).

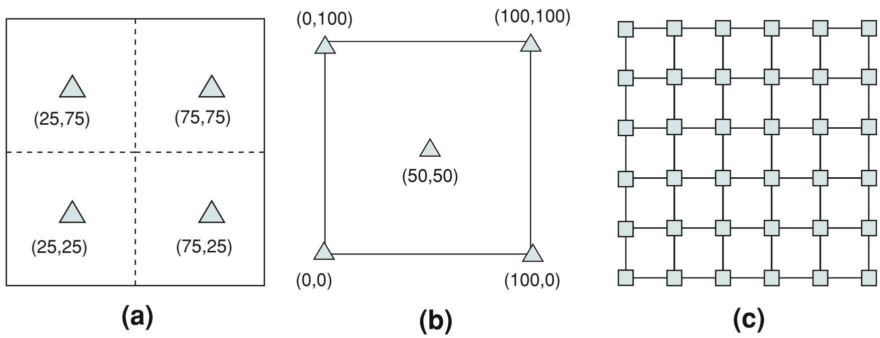

Fig. 1 Different SSD Approaches in the literature. **a** Sink Sites—Approach 1 (P1). **b** Sink Sites—Approach 2 (P2). **c** Sink Sites—Approach 3 (B1)

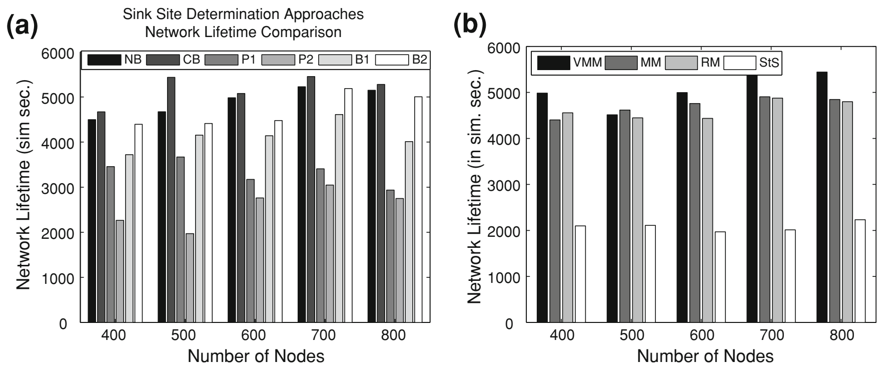

Fig. 2 Network Lifetime Comparison of SSD and Movement Algorithms. **a** SSD Approaches: Network Lifetime Comparison. **b** Network lifetime for 400 nodes (SSD = NB)

In the third approach, which comes from Basagni et al. [1], the area is divided into 3×3 (5×5) grids, totally 16 (36) corner points of sub-squares are taken as candidate migration points (B1 and B2 respectively). We evaluate the performance of our approaches (neighborhood-based set covering heuristic (NB), and coordinate-based (CB)) with these four methods.

As can be seen in Fig. 2a, both neighbor- and coordinate-based approaches perform better than other four in terms of network lifetime. The CB approach is three times better than P2 for 500 nodes as well. P1 has the best data latency (average hop count) because four different sites have been optimally placed in the center of the four grids (not shown here due to page limitations). Although the NB and CB approaches have a 25% worse data latency than P1, they have up to 60% better network lifetimes and better data latency than the other three in all cases as well. Figure 2b shows that VMM performs better than max–min (MM), random movement (RM) and static sink (STS) approaches in almost all cases (SSD is fixed to NB and transmission range is 35 m).

4 Conclusion

In this paper, we investigated sink site determination and movement strategy parts of the sink mobility problem. We propose two sink site determination algorithms and a movement strategy. We compare the performance of our algorithms with different approaches via simulation experiments. Our sink site determination algorithms perform better than the other four approaches (also lower data latency values than three of them) in the literature. Our movement strategy's (VMM) results are also better than the other three strategies almost in all cases.

References

1. Basagni, S., Carosi, A., Melachrinoudis, E., Petrioli, C., Wang, M.: Controlled sink mobility for prolonging wireless sensor networks lifetime. ACM J Wirel. Netw. (WINET) **14**, 831–858 (2007)
2. Heinzelman, W., Chandrakasan, A., Balakrishnan, H.,: Energy-efficient communication protocol for wireless microsensor networks. In: Proceedings of the 33rd International Conference on System Sciences (HICSS '00) (2000)
3. Papadimitriou, I., Georgiadis, L.: Energy-aware routing to maximize lifetime in wireless sensor networks with mobile sink. J. Commun. Softw. Syst. **2**, 141–151 (2006)